Imaging Spins

Scientific Achievement

The most remarkable feature of self-assembled or lithographically defined nanomaterials is the ability to change the mesoscopic and macroscopic behavior, so that material properties can be tailored for specific applications. Within these groups of materials the nanomagnets take a distinguished position. On the one hand their versatility opens potential applications in a wide range of areas, such as magnetic data storage, spintronic devices or targeted drug-delivery; on the other hand the understanding of their magnetic behavior is only possible by the description of temporal, spatial and field evolution of their spin states.

The Magnetic Films Group has been building a network of collaborations at major user facilities to characterize nanoscale spin behavior. By employing high-resolution Photo-Emission Electron Microscopy and Lorentz Transmission Electron Microscopy we were able to identify a size- and geometry-dependent transition from non-uniform (vortex-like) in-plane magnetization distribution to antiparallel collinear states in patterned F/N/F dot arrays, whereas the out-of-plane polarization of the magnetic vortex core ("up" or "down") was revealed using Magnetic Force Microscopy. Alternating ferro- and antiferromagnetic ordering phenomena in layer-by-layer grown Mn/Fe(001) nanoclusters was revealed *"in-situ"* using Spin-Polarized Scanning Tunneling Microscope. High temperature magnetic relaxation phenomena were explored in self-assembled Co dots grown at 780 K on Ru(0001) using Spin-Polarized Low Energy Electron Microscopy. Onion-like state and fine ripple spin distribution in lithographically defined ferromagnetic ring networks were imaged with a Magneto-Optical Indicator Films imaging technique, and confirmed with higher resolution by using Lorentz Transmission Electron Microscopy. Novel approach of Diffraction Magneto-Optics was employed to provide new insights on spatial symmetry of the magnetization reversal process

Significance

Nanomagnetism is an exciting area of research, equally important from fundamental and applied viewpoints. Understanding the behavior of geometrically confined magnetic materials relies on our ability to resolve their internal spin configurations. We employ advanced imaging tools to enable world-class nanomagnetism discoveries at the Materials Science Division and strengthen our collaborative links with major users facilities. Future efforts will be to develop imaging tools with improved spatial and/or temporal resolution that reveal new physics, such as time-resolved PEEM-3 at Advanced Light Source, phase-sensitive Transmission Electron Microscope at Electron Microscopy Center at MSD, low temperature and UHV MFM at MSD, and polarized neutron reflectometry at Spallation Neutron Source.

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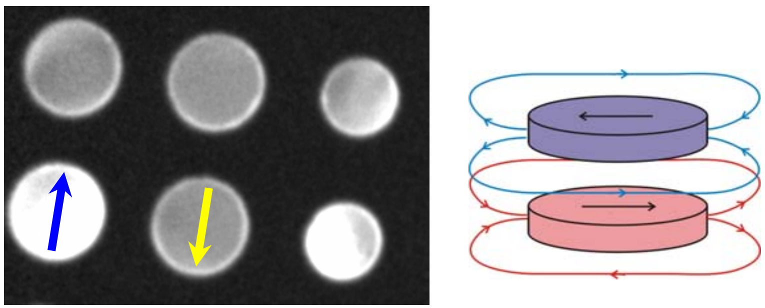
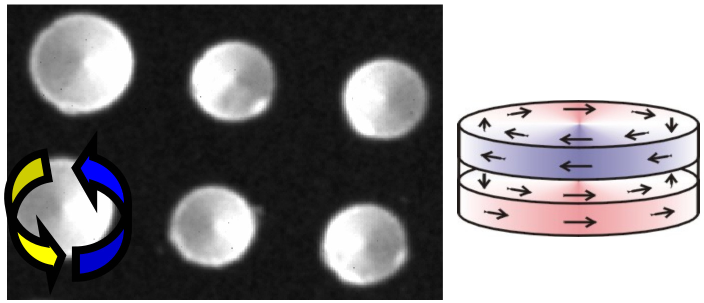
- **Nanomagnetism** **is an blossoming area of research, important from fundamental and applied viewpoints. We employ advanced imaging tools to enhance our nanomagnetism research while strengthening our collaborative links with major users facilities.**





- **Future** **efforts are to help develop imaging tools with spatial and/or temporal resolution that reveal new physics, such as time-resolved PEEM-3 at ALS, phase-sensitive TEM and low temperature and UHV MFM at MSD, and polarized neutron reflectometry at SNS.**

S. D. Bader, “Colloquium: Opportunities in Nanomagnetism”, Rev. Mod. Phys. 78, 1 (2006).

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